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AIR FORCE CIVIL ENGINEER CENTER

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Subject: Response to Timing of Shutdown of Steam Enhanced Extraction System
Site ST012 - Former Williams Air Force Base, Mesa, Arizona

Thank you for your letter on 7 March 2016 concerning the timing of shutdown of the Steam Enhanced Extraction (SEE) at the Former Liquid Fuel Storage Area (ST012) at the former Williams Air Force Base in Mesa, Arizona. The Air Force (AF) has prepared this response to document the current status with respect to SEE system performance and the plans for transition to enhanced bioremediation (EBR).

Transition Criteria. In making the decision to transition from SEE to EBR, the AF remains focused on the transition criteria established for ST012 in the Remedial Design and Remedial Action Work Plan (RD/RAWP). The Record of Decision Amendment 2 established that the transition criteria would be defined in the RD/RAWP and both the United States Environmental Protection Agency (EPA) and the Arizona Department of Environmental Quality (ADEQ) provided comment and agreed to the criteria documented in the RD/RAWP.

At the recent Base Realignment and Closure Cleanup Team (BCT) meeting in Phoenix on 15 March 2016, the Air Force presented data supporting achievement of the transition criteria sufficient to support a technology transition. Table 1 summarizes the conclusions presented.

Achievement of target temperatures and pressure cycling are readily demonstrated by the data. Steam injection has approached the guideline identified in the RD/RAWP and the actual pore volumes flushed (1.8) has exceeded the expected quantity (1.6). Mass removal rates and benzene concentrations have not consistently met numerical targets; however, it has been shown that the primary reason these targets have not been achieved is related to mass extracted from outside the thermal treatment zones (TTZs) (more information in Ongoing Mass Recovery section). The limitations on achieving these target criteria due to perimeter effects were identified in the RD/RAWP and it was not intended that any of the listed criteria be applied as an absolute requirement. The criteria summarized in Table 1 are to "be considered in total with the weight of evidence from the multiple lines being used for decisions" (RD/RAWP). Overall, the weight of evidence indicates that, while SEE is still removing mass, SEE has met the transition criteria goal of "significant decline in mass removal" and SEE contaminant mass removal effectiveness has diminished (RD/RAWP).

Table 1. Summary of Transition Criteria Status

Transition Criteria	Progress
Primary Criteria	
Target Temperature Achievement	• Target temperature achieved in all zones (LSZ above 235 ft bgs) • Steam breakthrough observed at all interior MPE wells
Mass Removal Status	• Total mass removal is 10.3% of peak (average) – mass removal rates are diminishing • Mass removal approaching target, further progress limited by perimeter contribution
Secondary Criteria	
Pressure Cycling Status	• Multiple pressure cycles have been completed in each zone (CZ = 5, UWBZ = 9, LSZ = 7)
Benzene Concentrations	• Benzene concentrations <500 µg/L in LSZ; suitable for transition to natural attenuation • Benzene concentrations at interior CZ and UWBZ locations <5,500 µg/L; suitable for transition to EBR
Steam Injection Status (guideline)	• 302.4 MM pounds injected versus 320 MM operations guide (94%) • Achieved average TTZ flushing of 1.8 pore volumes as water

Notes:
< - less than
% - percent
CZ – cobble zone
EBR – enhanced bioremediation
ft bgs – feet below ground surface
LSZ – lower saturated zone
MM – million
TTZ – thermal treatment zone
µg/L – micrograms per liter
UWBZ – upper water bearing zone

Ongoing Mass Recovery. Mass recovery that remains at ST012 is mostly coming from outside the TTZs based on the following observations (see weekly reports and March 2016 BCT presentation slides):

- Jar testing indicates greater light non-aqueous phase liquid (LNAPL) quantities in perimeter wells than interior wells
- Calculated benzene concentrations higher in perimeter wells than interior wells

- Mass removal rates have stabilized over last 30 days
- Benzene fraction in LNAPL not reducing which indicates that LNAPL is originating from outside the TTZ
- Pressure cycling does not result in significantly increased vapor concentrations
- LNAPL recovery decreases during pressurization and increases during depressurization
- Total mass is currently (February 2016) being removed at approximately 2,000 pounds per day. This represents 0.08 percent (%) of total removed to date
- LNAPL removal at less than 1,000 pounds per day. This represents 0.04% of total removed to date
- Current mass removals are similar to rates on 30 November 2014 (before subsurface was significantly heated)

Continued mass recovery regardless of whether the mass originates within or outside the TTZs is a good thing; however, the ability to further enhance removal outside the TTZ is limited. Steam injection has heated areas around and outside each TTZ, which has likely mobilized LNAPL through viscosity changes. The promotion of mass removal using SEE in areas outside the TTZs relies primarily on the transport of warm water. With each successive pressure cycle, the benefit of reheating to recover further mass in this area is diminished and after nine pressure cycles in the Upper Water Bearing Zone and five in the Cobble Zone, most of the LNAPL in this area that can be mobilized by the existing system has been mobilized. The steep hydraulic gradients generated in the January and current depressurization cycles have helped to recover this mobilized material. Longer steam pressurization events could potentially increase the extent of the heated area around the TTZs to increase mass removal; however, risk of mobilizing mass away from the extraction system would also increase. For this reason, longer more aggressive pressurization events are not recommended.

SEE and EBR Treatment Efficiency. The mass removal rate during SEE has and continues to exceed the mass removal rate during the Thermal Enhanced Extraction Pilot; however, comparisons of the two systems are not beneficial given the differences in the objectives, designs, and functional operations. The SEE system continues to remove mass, predominantly from outside the TTZs. SEE was not designed for efficient mass removal from outside the TTZs whereas the intended objective of EBR specified in the RD/RAWP is treatment of the LNAPL-impacted zones outside the SEE TTZs, and to the extent necessary, residual contamination within the TTZs.

EBR was intended as a follow-on technology once the performance of SEE has diminished. As presented in the March 2016 BCT meeting, the potential for LNAPL presence at the SEE perimeter was identified as early as the Focused Feasibility Study. In the RD/RAWP, which the EPA and ADEQ reviewed and approved, LNAPL presence outside the TTZs and the strategy of EBR to address mass in this area was presented. EBR implementation will address residual LNAPL causing exceedance of groundwater cleanup levels. In addition, extraction of LNAPL will continue during the post SEE extraction and EBR extraction period supplemented by individual well LNAPL removal as needed.

The SEE system is a more aggressive technology for mass removal than EBR and consequently would remove more mass per unit time than EBR. However, site conditions have reached the point where SEE is less efficient, less cost effective, and less green or sustainable than EBR. The geographic limitations encountered during SEE design and implementation limit its effectiveness outside the TTZs. EBR is a less energy intensive approach over longer time periods and therefore represents a greener remediation approach. It is also more flexible and can target the specific areas requiring treatment.

Mass Remaining and LNAPL Characterization. Estimates of mass remaining at ST012 have historically been based on understanding the extent of LNAPL-impacted areas and assumptions concerning LNAPL residual in these areas. The interpretation of LNAPL-impacted area is based on the available investigation locations with interpolation between locations. With each successive drilling activity, the extent of impacts are refined in three dimensions. LNAPL mass associated with LNAPL impacted areas has been calculated based on assumptions of literature-based residual and site-averaged total petroleum hydrocarbon values associated with LNAPL-impacted areas. As additional investigations are implemented (e.g., borings during multiple phases of EBR), the LNAPL extent and mass estimates will continue to be refined; however, there will continue to be uncertainty regarding these estimates.

The general trend in estimated mass at ST012 has been decreasing as additional data is incorporated into estimates. The mass recovered during SEE also presents an opportunity to calibrate previous estimates with actual site data. The combination of the approximately 2.5 million pounds of mass removed and the indications that most of the mass removal has been originating from outside the TTZ for at least a few months, support previously presented lower range mass estimates. In light of this, the presence of mobile LNAPL pulled in from outside the TTZ likely represents former residual LNAPL that has been mobilized under the influence of the heated water. LNAPL mobility will decrease as post SEE temperatures decline. Based on the available information, 300,000 gallons of LNAPL is an upper range estimate of remaining LNAPL at the site with a more likely range of 175,000 to 200,000 gallons (these values are consistent with the distribution estimates provided in the RD/RAWP).

Effectiveness of EBR. EBR will be focused on addressing dissolved phase contamination and depleting remaining LNAPL of contaminants of concern and other soluble components. Depletion of source zones by biological and other methods has been demonstrated through Natural Source Zone Depletion (NSZD) over long timeframes (ITRC, 2009). These mechanisms are typically limited under ambient conditions by availability of terminal electron acceptor (TEA) and mass dissolution rates. Dissolution rates have been enhanced in areas around the TTZs by SEE and the EBR is designed to increase TEA availability (sulfate) by more than 200 times during Phase 1 injections compared to natural annual TEA fluxes at ST012. Consistent with NSZD mechanisms, it is expected that a portion of the LNAPL mass will not be readily soluble (EPA, 1999) and will remain at the site, primarily as a residue associated with the deep soils.

Path Forward. To summarize, evaluation of the RD/RAWP transition criteria indicates that the site is ready for transition. The primary mass currently being removed by the SEE system originates outside the TTZs. The SEE system is removing mass from outside the TTZ but at low and decreasing efficiency because it was not designed to address this area. EBR has been designed to treat post SEE contaminant mass located inside and outside the TTZs. EBR will degrade dissolved phase contamination and deplete the soluble fraction of remaining LNAPL to support achievement of groundwater cleanup objectives. There is uncertainty concerning the exact extent of LNAPL; however, this will continue to be refined based on information gathered during multiples phases of EBR. The mass extracted during SEE provides indications that the remaining mass present outside the TTZs is lower than conservative historical estimates which supports the ability of EBR to further degrade what remains and set ST012 up to achieve groundwater cleanup objectives within the expected remedial timeframe. In addition, the soil vapor extraction (SVE) system will remain operational after SEE until contaminant cleanup levels and remedial action objectives are achieved for the deep soil SVE remedy.

The system is currently in a depressurization cycle with steam terminated in all three zones as of 4 March 2016. The plan is to extend this depressurization period during which vapor and liquid extraction will continue. Influent concentrations, mass recovery, and temperatures will be closely monitored during the extended depressurization. Unless data indicates further heating is critical to mass removal rates beyond the TTZ (i.e., mass removal rate is closely tied to perimeter temperatures), it is expected that this depressurization will be the last one for the site and this depressurization will be considered part of the post-steam extraction period. Vapor and liquid extraction will be maintained at the site during the post-steam extraction period so that LNAPL and contaminant mass can be recovered. The post-steam extraction period will also set up the site with perimeter temperatures that can support the successful implementation of EBR. The post-steam extraction period duration is estimated to be 6 to 12 weeks. Weekly reports and status updates will continue to be distributed.

Please contact me at (315) 356-0810, ext. 204 or catherine.jerrard@us.af.mil if you have any questions regarding this letter.

Sincerely,

CATHERINE JERRARD
BRAC Environmental Coordinator

References:

Interstate Technology Regulatory Council (ITRC), 2009. *Evaluating Natural Source Zone Depletion at Sites with LNAPL*. April 2009.

Environmental Protection Agency (EPA), 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive Number 9200.4-17P).